

1 What is claimed is:

2 1. An apparatus for use in a mass spectrometer to enhance
3 the performance thereof, said apparatus comprising:

4 means for detecting sample ions;

5 means for trapping sample ions; and

6 a differential amplifier;

7 ~~wherein a space encompassed by said detecting means is also~~
8 encompassed by said trapping means;

9 wherein said sample ions are trapped within said space by
10 said trapping means by application of electrical potentials onto
11 said trapping means; and

12 wherein said sample ions are detected by said detecting
13 means.

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15 2. An apparatus according to claim 1, wherein said means
16 for detecting sample ions is arranged in a substantially
17 cylindrical manner.

18
19 3. An apparatus according to claim 1, wherein said
20 detecting means utilizes charge induction to detect ions.

1 4. An apparatus according to claim 1, wherein said sample
2 ions are detected in a manner similar to that in an FTICR mass
3 spectrometer.

4
5 5. An apparatus according to claim 1, wherein said
6 trapping means comprises four RF electrodes.

7
8 6. An apparatus according to claim 1, wherein said
9 detection means comprises four detection electrodes.

10
11 7. An apparatus according to claim 1, wherein said
12 apparatus is linear.

13
14 8. A multipole device according to claim 1, wherein
15 elements of said trapping means are held at a DC potential to
16 trap ions within said detecting means.

1 9. A multipole device for transferring, trapping and
2 analyzing ions in a mass spectrometer, said multipole device
3 comprising:

4 a plurality of electrodes, said electrodes comprising a
5 plurality of RF electrodes, and at least one
6 first; and

7 second detection electrodes;

8 at least two trapping electrodes; and

9 a differential amplifier having first and second
10 inputs;

11 wherein said plurality of electrodes are arranged such that
12 no two RF electrodes are adjacent and no two detection electrodes
13 are adjacent;

14 wherein all of said first detection electrodes are
15 electrically connected and all of said second detection
16 electrodes are electrically connected;

17 wherein said first detection electrodes are connected to
18 said first input and said second detection electrodes are
19 connected to said second input;

20 wherein one of said trapping electrodes is positioned at
21 each end of said plurality of electrodes such that when an

1 appropriate DC potential is applied thereto said ions become
2 trapped within said plurality of electrodes; and

3 wherein said differential amplifier measures the potentials
4 on said detection electrodes to determine the m/z ratio of said
5 ions.

6
7 10. A multipole device according to claim 9, wherein said
8 plurality of electrodes are arranged in a substantially circular
9 manner.

10
11 11. A multipole device according to claim 9, wherein said
12 plurality of electrodes detect trapped ions by charge induction.

13
14 12. A multipole device according to claim 9, wherein said
15 plurality of electrodes detect ions in the manner of FTICR mass
16 spectrometry.

17
18 13. A multipole device according to claim 9, wherein said
19 apparatus contains four RF electrodes, and four detection
20 electrodes.

1 14. A multipole device according to claim 9, wherein said
2 device is linear.

3
4 15. A multipole device according to claim 9, wherein said
5 RF electrodes of said device have the same potential and
6 frequency as said trapping electrodes.

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8 16. A multipole device according to claim 9, wherein said
9 device is further comprised of a single set of said RF
10 electrodes, and said detection electrodes divide the multipole
11 device into an analyzing section positioned between two trapping
12 sections.

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14 17. A multipole device according to claim 16, wherein said
15 detection electrodes in said trapping sections are held at a DC
16 potential to trap ions in said analyzing section.

1 18. A linear multipole device for transferring, trapping
2 and analyzing ions in a mass spectrometer, said multipole device
3 comprising:

4 four RF electrodes;

5 four electrodes comprising two first and two second
6 detection electrodes;

7 two trapping electrodes; and

8 a differential amplifier having first and second
9 inputs;

10 wherein said electrodes are arranged such that no two RF
11 electrodes are adjacent and no two detection electrodes are
12 adjacent;

13 wherein both of said first detection electrodes are
14 electrically connected and both of said second detection
15 electrodes are electrically connected;

16 wherein said first detection electrodes are connected to
17 said first input and said second detection electrodes are
18 connected to said second input;

19 wherein one of said trapping electrodes is positioned at
20 each end of said electrodes such that when an appropriate DC
21 potential is applied thereto said ions become trapped within said

1 plurality of electrodes; and

2 wherein said differential amplifier measures the potentials
3 on said detection electrodes to determine the m/z ratio of said
4 ions.

5
6 19. A linear multipole device according to claim 18,
7 wherein all of said electrodes are circularly arranged.

8
9 20. A linear multipole device according to claim 18,
10 wherein said detection electrodes detect trapped ions by charge
11 induction.

12
13 21. A linear multipole device according to claim 18,
14 wherein said detection electrodes detect said ions in the manner
15 of FTICR mass spectrometry.

16
17 22. A linear multipole device according to claim 18,
18 wherein said RF electrodes have the same potential and frequency
19 as said trapping electrodes.

1 23. A linear multipole device according to claim 18,
2 wherein said detection electrodes divide said device into three
3 sections comprising one analyzing section located between two
4 trapping sections.

5
6 24. A method for analyzing ions in a mass spectrometer,
7 ~~said method comprising the steps of:~~

8 directing ions into a multipole device having an
9 analysis region positioned between, and coaxially
10 with, first and second trapping regions;
11 trapping said ions within said analysis region by
12 creating electric fields across said trapping
13 regions; and
14 analyzing said ions;

15 wherein said analyzing region includes exciting said ions
16 within said analysis region and detecting said ions from within
17 said analysis region.

18
19 25. A method according to claim 24, wherein said ions are
20 detected within said analysis region by a plurality of detection
21 electrodes.

1 26. A method according to claim 25, wherein said plurality
2 of detection electrodes comprises four detection electrodes,
3 allowing detection of said excited, ions in two cycles.
4

5 27. A method according to claim 24, wherein said trapping
6 regions are held at a higher DC potential than said analysis
7 region to form a substantially homogeneous quadrupolar field
8 within said analysis region.

9
10
11 28. A method according to claim 24, wherein said exciting
12 is achieved by applying an electrical pulse between electrodes of
13 said analysis region.

14
15 29. A method according to claim 28, wherein said exciting
16 causes said ions to move in a substantially circular orbit around
17 a central axis of said analysis region.

18 30. A method according to claim 28, wherein said exciting
19 causes said ions to move in a substantially oval orbit around a
20 central axis of said analysis region.
21

1 31. A method according to claim 24, wherein said ions are
2 detected using charge induction.

3
4 32. A method according to claim 24, wherein said ions are
5 detected in the manner of FTICR mass spectrometry.

1 33. A mass analyzer comprising:

2 at least four RF electrodes;

3 at least four detect electrodes; and

4 at least two DC electrodes;

5 wherein said RF electrodes and detect electrodes are
6 arranged in a cylindrically symmetric manner about a central
7 axis;

8 wherein said RF electrodes and detect electrodes have inner
9 surfaces which are arc shaped;

10 wherein every RF electrode is arranged between and parallel
11 with two detect electrodes;

12 wherein every detect electrode is arranged between and
13 parallel with two RF electrodes;

14 wherein sample ions are substantially trapped on the axis of
15 said mass analyzer by the action of an RF electric field
16 generated via said RF electrodes;

17 wherein said sample ions are substantially prevented from
18 exiting the ends of said mass analyzer by the action of a DC
19 electric field generated via said DC electrodes; and

20 wherein said detect electrodes are used to detect the ions
21 in said mass analyzer.

1 34. An apparatus according to claim 33, wherein said
2 detecting means utilizes charge induction to detect ions.
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4 35. An apparatus according to claim 33, wherein at least
5 some of said RF electrodes, DC electrodes, or detect electrodes
6 extend through a pumping restriction.
7

8 36. An apparatus according to claim 33, wherein at least
9 some of said RF electrodes, DC electrodes, or detect electrodes
10 are used to assist in the transport of ions from an ion source
11 into said mass analyzer.
12

13 37. An apparatus according to claim 35, wherein said
14 electrodes which extend through said pumping restriction are used
15 in part to assist in the transport of ions from an ion source
16 into said mass analyzer.
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